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(54) Body posture changes detecting system

(57) In a body posture changes detecting system means (16) are provided for recording electrocardiograms. Analyzer means (20, 22, 24, 26, 28) are futher arranged to determine changes in the body posture of a patient (18) from changes in the morphology of the recorded electrocardiograms.

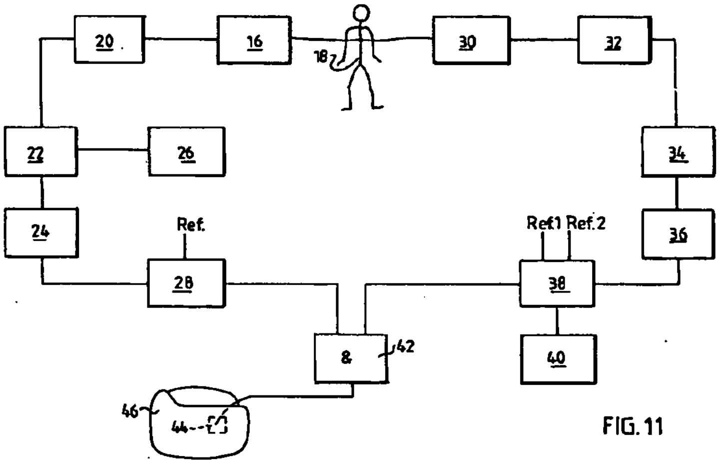

FIG. 11

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Description

Technical Field

The present invention relates to a body posture changes detecting system.

Background Art

Most sensors for measuring different physiological parameters, like pressure, electrical impedance etc., is effected by changes in the body posture. Thus more accurate and reliable information can be obtained if the body posture is known. In US, A, 5 370 667 a device and a method for automatically adjusting tachycardia recognition criteria based on detected physical activity of the patient. In this way it is possible to discriminate between physiological and pathological tachycardias. The activity sensor which is an accelerometer of piezoelectric, piezoresistive or piezocapacitive type determines the activity status of the patient, including the position of the patient, and this information is used to adjust a threshold rate for the tachycardia recognition criterion of an ECG.

Furthermore, the body responds to a change in body posture from supine to standing by a transient increase in the heart rate, see US, A, 5 354 317. In this patent an apparatus and a method for cardiac pacing responsive to patient position are described, the same types of accelerometer as mentioned above being proposed for detecting changes in posture of the patient and this information being used for controlling the pacing rate as physiologically correct as possible.

It has now been observed that body posture changes result in immediate changes in the morphology of the ECG. Thus figure 1 shows average ECG:s for a number of cardiac cycles with the patient in supine position and in a sitting upright position respectively. As appears from this figure the two positions of the patient are reflected in a characteristic difference in the surface ECG after the QRS-complex. Figures 2 and 3 illustrate average IECG for a number of cardiac cycles for three different positions, standing, sitting and supine, and for two patients respectively. Also in this figures characteristic changes in the average IECG:s are observed for the different body postures of the patient, these differences being more pronounced in certain portions of the cardiac cycle then in other portions.

The purpose of the present invention is to propose a new body posture changes detecting system which is based on the observed changes in surface ECG:s as well as in IECG:s resulting from changes in the body posture.

Disclosure of the Invention.

This purpose is obtained, according to the invention, by a body posture changes detecting system having means for recording electrocardiograms and analyzer means to determine changes in the body posture of a patient from changes in the morphology of the recorded electrocardiograms.

According to advantageous embodiments of the system according to the invention the analyzer means comprise averaging means for determining a first mean value of a specific portion of electrocardiograms recorded during a predetermine, first number of cardiac cycles, and a second mean value of the same specific portion of electrocardiograms recording during a predetermined, second number of subsequent cardiac cycles, and means for detecting changes in the body posture from the relation between these mean values. The analyser means comprise means for forming the difference between the first mean value and said second mean value and said detecting means comprise first comparison means for comparing said difference with predetermined threshold values for determining changes in posture from the relation between this difference and the threshold values. Thus the mean or average value of the specific portion of electrocardiograms from e.g. the ten latest cardiac cycles is calculated and compared with the average value of this portion of electrocardiograms from the two next coming cardiac cycles. If the difference between this two average values exceeds a given threshold this indicates a change in body posture.

According to another advantageous embodiment of the system according to the invention said specific portion of electrocardiograms comprises the T-wave of a cardiac cycle. As appears from the discussion above the ST and T segment of the ECG have superior predictive power of posture changes than the QRS-complex. Therefore using the difference between T-segments or - waves is most appropriate.

According to yet another advantageous embodiment of the system according to the invention said first comparison means is arranged to determine an increase of said difference above an upper, first threshold value as indication of changed posture from supine to standing and a decrease of said difference below a lower, second threshold value as indication of changed posture from standing to supine. A change in posture from supine to standing results in a change, e.g. an elevation, of the T-segment. Consequently, if the T-segment then has increased, the patient has changed posture from supine to standing and, if the T-segment has decreased, the patient has changed posture from standing to supine. The changes in the electrocardiogram for certain body posture changes can be determined in advance for a patient in question, and if the the body posture changes detecting system according to the invention is used for controlling a heart stimulator, the control means of the heart stimulator are then adapted to the detected changes in the electrocardiograms for given body posture changes, such that the heart stimulator is controlled in the desired manner in response to body posture changes of the patient.

According to still another advantageous embodiment of the system according to the invention also an accelerometer is provided to determine changes in the posture of the patient. Thus by adding accelerometer measurements to the EGG measurements improved reliability in the detected body posture changes is obtained.

According to another advantageous embodiment of the system according to the invention an AND-gate is connected to said first and second comparison means to receive as input signals output signals from these comparison means indicating posture changes, said AND-gate delivering an output signal representing a specific change in posture only if both its input signals indicate this specific change in posture. Thus an indication of a certain change in body posture is only obtained if both the ECG measurement and the accelerometer measurement indicate this same change in the body posture.

According to yet another advantages embodiment of the system according to the invention a memory is provided to store the latest detected posture change. It will then be known whether the patient is standing or is laying down.

According to the invention also a heart stimulator is provided comprising a body posture changes detecting system as defined above, and control means connected to said detecting system for controlling the stimulation rate in response to detected posture changes. More precisely, in response to a detected posture change of the patient from supine to standing, said control means are disposed to increase the stimulation rate to an increased value exceeding the normal value for a patient in standing position and then lower the stimulation rate to said normal value within a predetermined period of time after said increase. By controlling the heart stimulator to produce such a temporary increase in the stimulation rate a physiologically proper increase of the stimulation rate is produced when the body posture changes from supine to standing.

Brief Description of the Drawings

To explain the invention more in detail as examples chosen embodiments of the detecting system according to the invention will now be described more in detail with reference to the accompanying drawings, on which figures 1-3 show average values of ECG:s recorded for different body postures, figure 4 is a flow diagram for describing the operation of a first embodiment of the detecting system according to the invention, figure 5 shows the circuitry of an accelerometer used in the detecting system according to the invention, figures 6 and 7 show the obtained accelerometer signal, unfiltered and filtered respectively, when the body posture is changed, figures 8 and 9 show the accelerometer signal, unfiltered and filtered respectively, when the body posture is changed and for different activities of the patient, figure 10 is a flow diagram for explaining the operation of the accelerometer part of the detecting system according to the invention, and figure 11 is a block diagram of an embodiment of the detecting system according to the invention combining recorded ECG:s and accelerometer signals for determining body posture changes.

Description of Preferred Embodiments

Figures 1-3 show, as explained above, surface ECG:s and IECG:s with the signal intensity shown on an arbitrary voltage scale as a function of time. As discussed above the differences between the ECG signals for different body postures are most pronounced in the ST and T segments of the cardiac cycle and these segments of the ECG:s are therefore preferably used for the detecting system according to the invention.

In figure 4 a flow diagram is shown for describing a first embodiment of the detecting system according to the invention in which body posture changes are detected from IECG:s.

In the setup phase 1 IECG:s are recorded and averaged for 10 heartbeats or cardiac cycles. The sampling of the waveform is triggered by the QRS complex, or, where appropriate, by a cardiac stimulation pulse. After an event is triggered the sampling circuit is delayed for roughly 300 ms and then it samples for 100 ms. Approximately 10 samples should be acquired during a cardiac cycle. The samples are taken at a time in the cardiac cycles corresponding to the T-wave. The average value is stored in a memory. It is of course possible , where appropriate, to sample larger portions of a IECG.

In step 2 a new heartbeat is sampled according to the procedure described under step 1.

At step 3 the new values are subtracted from the stored average values at each of the 10 sample points.

In step 4 the sum of the differences D obtained in step 3 is compared to a threshold value and depending on the results of this comparison the operation continuous to step 5, step 6 or step 8. The threshold value has to be established experimentally or may even have to be set for each individual. If the absolute value of the difference D is less than the threshold value the algoritm illustrated in figure 4 only updates the average value and cycles back to step 2, at step 5. If the difference D is greater than the threshold value this indicates a posture change, e.g. from standing to sitting position. However, the exact position change or transition indicated may differ from individual to individual. If the difference D is less than the negative threshold value an opposite posture change or transition is indicated, e.g. from sitting to standing position, in step 6.

In step 7 and 9 the running average value is updated. Since a body change or transition has taken place the new value shall have greater impact compared to the old values. In the example shown in figure 4 the new value is given the weight 3, however, other weights can of course be chosen.

The above described embodiment of the system for detecting body posture changes can include an accelerometer, e.g. a piezoelectric sensor, for determining body posture changes from measured accelerations.

Figure 5 shows a piezoelectric accelerometer 12 connected to an operation amplifier 14. The accelerometer 12 has a capacitance of about 700 pF which together with the resistor R_3 form a high pass filter with a cut-off frequency of 0,2 Hz for R_3=1 Gohm. Through the high pass filtering DC-components are removed from the signal. The supply voltage V_{cc} can be chosen to ±9V and the amplification of the amplifier circuit is $1+R_1/R_2$ □ 100 times for R_1 = 100 kohm and R_2 = 1 kohm. R_5 is a trimming potentiometer used for adjusting the offset, when the inputs of the amplifier circuit are open. The components of the amplifier circuit are preferably provided on a printed circuit card and the accelerometer is attached to a cap bracket fixed to the circuit card.

Figures 6 and 7 show the signal obtained from a patient, who lays himself down and stands up, by the accelerometer and amplifier circuit shown in figure 5. Figure 7 shows the signal in figure 6 after low pass filtering.

Figure 8 shows the signal obtained with the accelerometer and the amplifier circuit in figure 5 from a patient who is changing position from supine to standing, who is walking at the place, running at the place and jumping at the place as indicated in figure 9. Figure 9 shows the signal in figure 8 in a filtered version where the offset is reduced. The signal is also low pass filtered with a second order Butterworth filter with a cut-off frequency of 0,2 Hz. Figure 9 illustrates that the filtering is effective in getting rid of signal contributions from body movements usually used for rate response control, yet the change of body posture can be clearly extracted also from the filtered accelerations.

Figure 6-9 show the signals in volts as a function of time.

Especially figures 7 and 9 show that the accelerometer signal after suitable processing is well suited for detecting body posture changes. Thus the exceeding of an upper threshold by the signal can form an indication of a body posture change from standing to supine and the decrease of the signal below a lower threshold value can form an indication of a body posture change from supine to standing.

A flow diagram illustrating the determination of body posture by the accelerometer signal is shown in figure 10. In step 1, the setup phase, the variable p is set to the body posture standing or laying according to the actual body posture. Steps 2 to 5 wait for a change in body posture.

In step 2 the next sample of the AD-converted accelerometer signal is taken.

In step 3 the signal is low pass filtered with a second order Butterworth filter with a cut-off frequency of 0,2 Hz.

In step 4 the output value x of the low pass filter is red.

In step 5 the absolute value of x is compared with a threshold value to determine whether a change in body posture has occurred or not. Depending on the result the operation cycles back to step 2 or continues to step 6. If no body posture change is detected the operation is restarted from step 2.

Steps 6 to 8 determine a new body posture as a result of $|x| >$ threshold value.

If the body posture is laying, p=laying, the operation continuous from step 6 to step 7. If the existing body posture is standing, p=standing, the operation continuous from step 6 to step 8.

In step 7 the body posture is changed from laying to standing.

In step 8 the body posture is changed from standing to laying.

Steps 9 to 12 wait until the measured pulse due to changes in body posture has passed away.

In step 9 a new value is sampled of the accelerometer signal.

In step 10 the signal is filtered with a second order Butterworth filter with a cut-off frequency of 0,2 Hz.

In step 11 the output value x of the low pass filter is red.

In step 12 the absolute value of x is compared to a threshold value and if the absolute value of x is less than the threshold value the operation is cycled back to step 9, otherwise it cycles back to step 2.

In figure 11 a blockdiagram is shown of an embodiment of the detecting system according to the invention in which the ECG measurements are combined with accelerometer measurements.

Thus an ECG recorder 16 is connected to a patient 18 and the ECG signal is A/D converted at 20. In averaging means 22 an average value of the ten latest T-waves or the ten latest ST segments is calculated and compared with the average value of the two next coming T waves or ST segments, in the differentiator 24. The operation of the averaging means 22 is controlled by controlling means 26.

In a comparator 28 the difference between the two above mentioned average values is compared to a threshold or reference value and if the T wave or ST segment has increased the patient has changed posture from supine to sitting or standing and if the T wave or ST segment has decreased the patient has changed posture from standing or sitting to supine, cf. figures 1-3.

An accelerometer 30 is also measuring movements and posture changes of the patient 18. The output signal from the accelerometer 30 is amplified and high pass filtered in a circuit according to figure 5, at 32. By the high pass filtering DC components are filtered away from the signal to get rid of the offset from the amplifier. The signal is then A/D converted and low pass filtered, at 34 and 36 respectively. The low pass filter 36 is preferably a second order Butterworth filter with a cut-off frequency of 0,2 Hz, and by this low pass filtering frequency components related to other body movements than body posture changes are filtered away, as described above.

In the comparator 38 the low pass filtered signal is compared to threshold or reference values to determine body posture changes of the patient 18. If the signals exceed an upper threshold, Ref 1, this indicates that the body posture changes from standing to supine, and if the signal decreases below a lower threshold, Ref 2, this indicates that the body posture changes from supine to standing, cf. figures 6 and 7. A memory 40 is connected to the comparator 38 to store the last detected posture change. It is then known whether the patient is standing or is in a supine position.

The outputs of the comparators 28 and 38 are connected to the inputs of an AND-gate 42, the output of which is connected to control means 44 of a pacemaker 46, such that the stimulation rate of the pacemaker 46 is controlled by detected body posture changes. In this way the pacemaker 46 can be operated as physiologically correct as possible. Thus if a posture change from supine to standing is detected the stimulation rate is increased for about 5 seconds, whereupon the stimulation rate is gradually lowered to a "normal" rate for a standing patient.

By an AND combination of the ECG and the accelerometer measurements an improved reliability of the detecting system is obtained. However, as body posture changes are detectable by each of the ECG measurements and the accelerometer measurements an OR type combination of the two kinds of measurements could be used too.

The detecting system according to the invention can also be used for improving the accuracy and reliability of other kinds of measurements. As mentioned in the introduction of this specification a body posture change of a patient gives rise to strong artefacts in e.g. impedance measurements or blood pressure measurments on the patient. By using the body posture changes detecting system according to the invention in connection with such measurements it is possible to eliminate or compensate for such artefacts related to body posture changes.

Claims

1. A body posture changes detecting system, **characterized in** that means (16) are provided for recording electrocardiograms and in that analyzer means (20,22,24,26,28) are arranged to determine changes in the body posture of a patient (18) from changes in the morphology of the recorded electrocardiograms.

2. The system according to claim 1, **characterized in** that said analyzer means comprise averaging means (22) for determining a first mean value of a specific portion of electrocardiograms recorded during a predetermined, first number of cardiac cycles, and a second mean value of the same specific portion of electrocardiograms recorded during a predetermined, second number of subsequent cardiac cycles, and means (28) for detecting changes in the body posture from the relation between these mean values.

3. The system according to claim 2, **characterized in** that said analyzer means comprise means (24) for forming the difference between said first mean value and said second mean value and in that said detecting means comprise first comparison means (28) for comparing said difference with predetermined threshold values for determining changes in posture from the relation between this difference and the threshold values.

4. The system according to claim 3, **characterized in** that said first comparison means (28) is arranged to determine an increase of said difference above an upper, first threshold value as indication of changed posture from supine to standing and a decrease of said difference below a lower, second threshold value as indication of changed posture from standing to supine.

5. The system according to any of claims 2 through 4, **characterized in** that said specific portion of electrocardiograms comprises the T-wave of a cardiac cycle.

6. The system according to any of the claims 1 through 5, **characterized in** that an accelerometer (30) is provided to determine changes in the posture of the patient (18).

7. The system according to claim 6, **characterized in** that processing means (32) are provided for processing signals from the accelerometer (30) and in that second comparison means (38) is disposed to compare the processed signals with predetermined threshold values for determining changes in posture from the relation between these signals and the threshold values.

8. The system according to claim 7, **characterized in** that said second comparison means (38) is arranged to determine an increase of said signals above an upper, first limit value as indication of posture change from supine to standing and a decrease of said signals below a lower, second limit value as indication of changed posture from standing to supine.

9. The system according to any of the claims 6 through 8, **characterized in** that the accelerometer (30) comprises a piezoelectric, piezocapacitive or a piezoresistive sensor.

10. The system according to any of the claims 7 through 9, **characterized in** that an AND-gate (42) is connected to said first and second comparison means (28,38) to receive as input signals output signals from these comparison means indicating posture changes, said AND-gate delivering an output signal representing a specific change in posture only if both its input signals indicate this specific change in posture.

11. The system according to any of the preceding claims, **characterized in** that a memory (40) is provided to store the latest detected posture change.

12. A heart stimulator, **characterized by** a body posture changes detecting system according to any of the claims 1 through 11 and by control means (44), connected to said detecting system for controlling the stimulation rate in response to detected posture changes.

13. The heart stimulator according to claim 12, **characterized in** that, in response to a detected posture change of the patient from supine to standing, said control means (44) are disposed to increase the stimulation rate to an increased value exceeding the normal value for a patient in standing position and then to lower the stimulation rate to said normal value within a predetermined period of time after said increase.

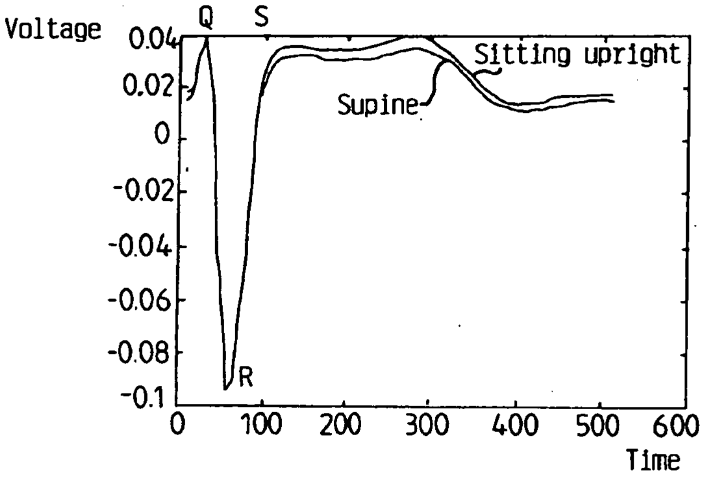

FIG.1

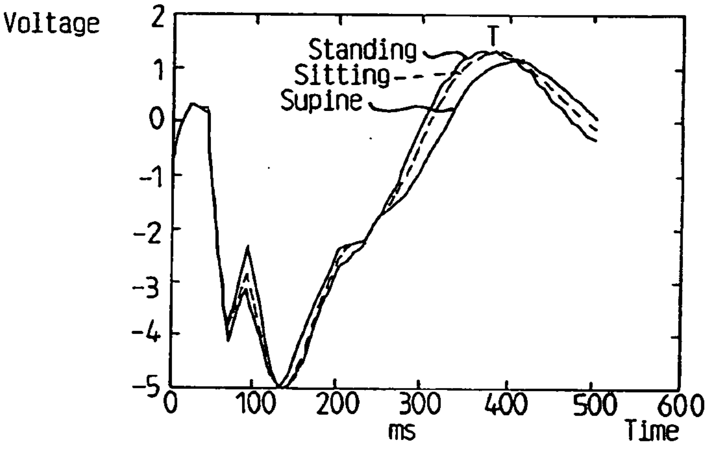

FIG. 2

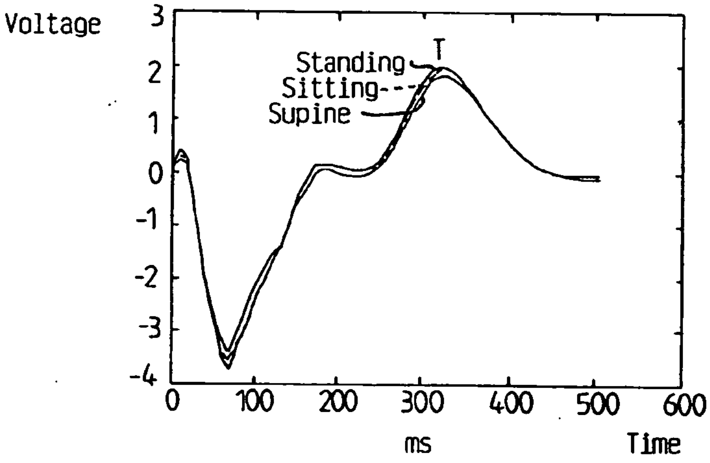

FIG.3

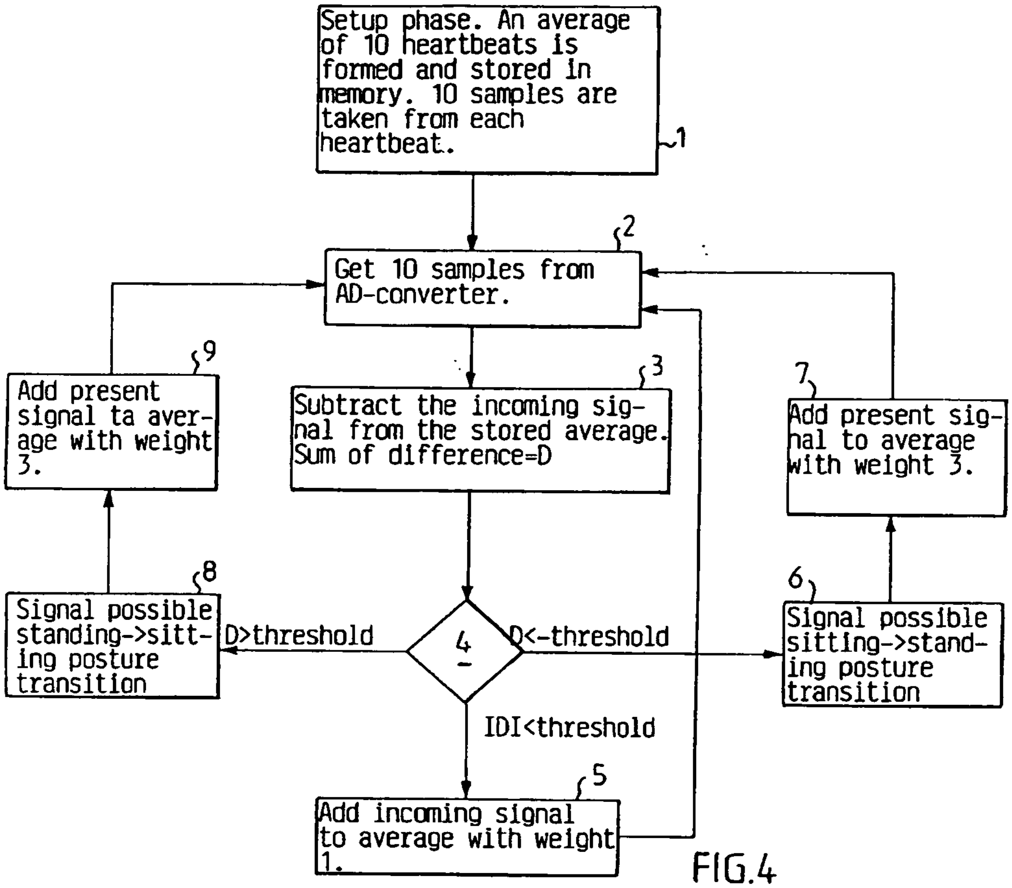
Setup phase. An average of 10 heartbeats is formed and stored in memory. 10 samples are taken from each heartbeat.
1
2
Get 10 samples from AD-converter.
9
Add present signal ta average with weight 3.
3
Subtract the incoming signal from the stored average. Sum of difference=D
7
Add present signal to average with weight 3.
8
Signal possible standing->sitting posture transition
D>threshold
4
D<-threshold
6
Signal possible sitting->standing posture transition
IDI<threshold
5
Add incoming signal to average with weight 1.

FIG.4

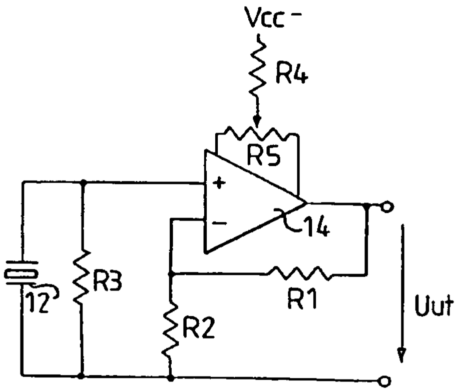
Vcc -
R4
R5
+
−
14
R3
12
R1
R2
Uut

FIG.5

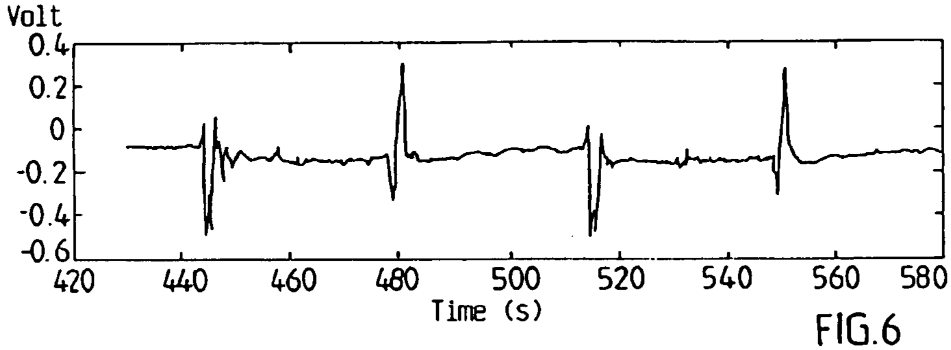

FIG.6

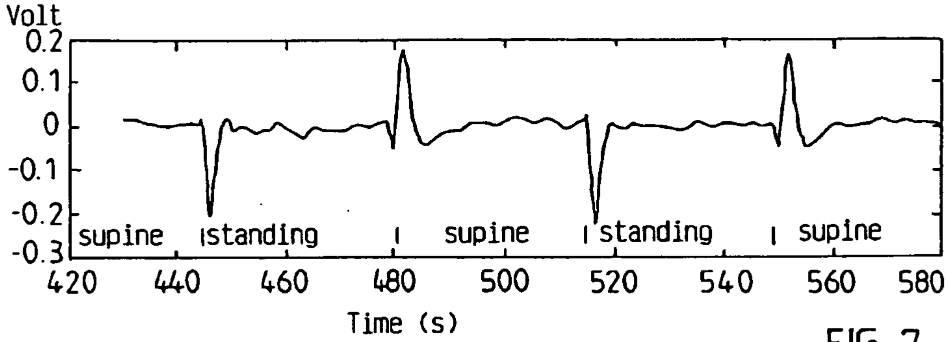

FIG. 7

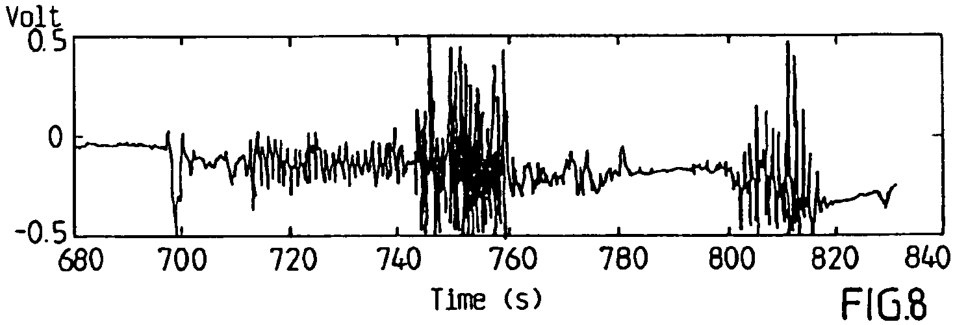

FIG.8

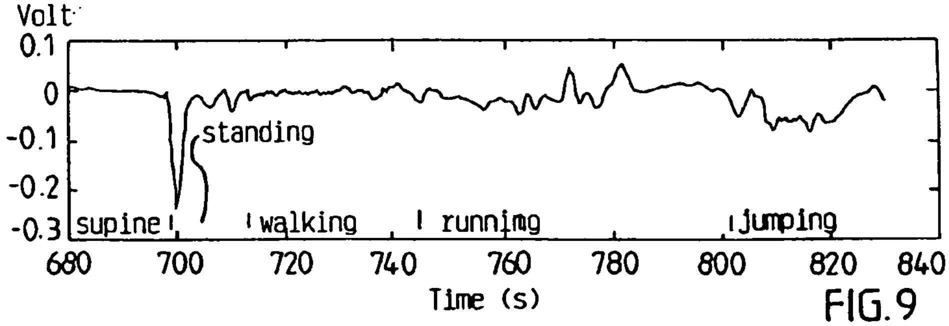

FIG.9

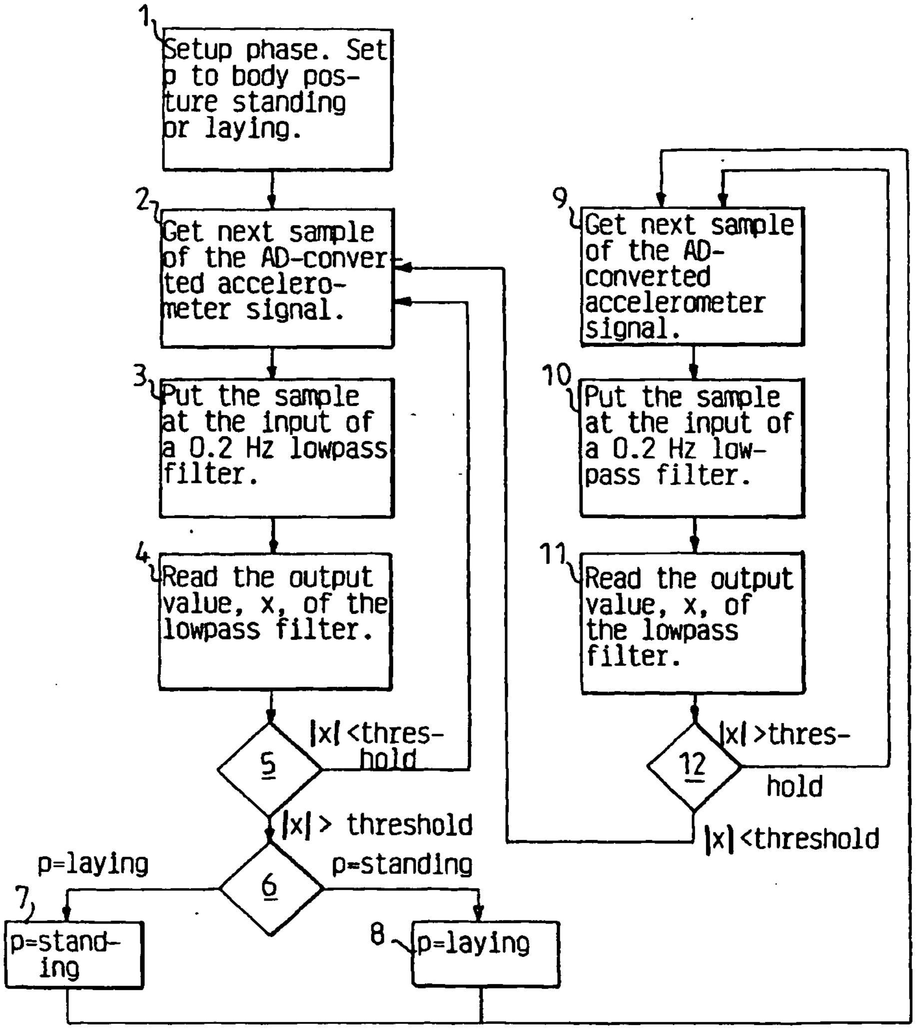
1
Setup phase. Set p to body posture standing or laying.
2
Get next sample of the AD-converted accelerometer signal.
3
Put the sample at the input of a 0.2 Hz lowpass filter.
4
Read the output value, x, of the lowpass filter.
5
|x|<threshold
|x|> threshold
6
p=laying
p=standing
7
p=standing
8
p=laying
9
Get next sample of the AD-converted accelerometer signal.
10
Put the sample at the input of a 0.2 Hz lowpass filter.
11
Read the output value, x, of the lowpass filter.
12
|x|>threshold
|x|<threshold

FIG.10

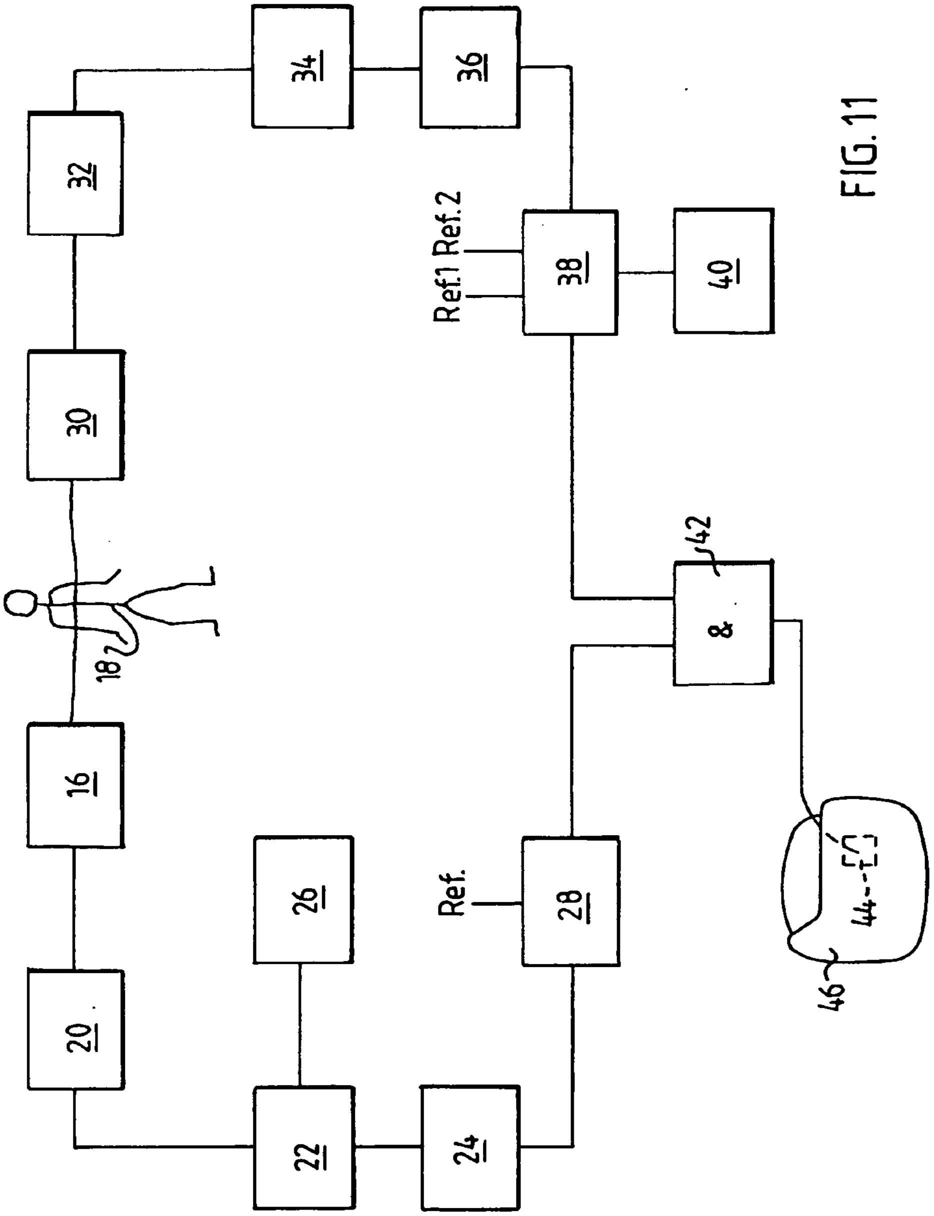

FIG. 11

European Patent
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EUROPEAN SEARCH REPORT

Application Number
EP 97 11 8609.3

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.6)
A	US 5472453 A (E.ALT), 5 December 1995 (05.12.95) * abstract * --	1-13	A61B 5/0402 A61N 1/365
A	Patent Abstracts of Japan, Vol 96,No 3 abstract of JP 80-56914 A (SYSTEM FOR ANALYZING ELECTROCARDIOGRAM), 5 March 1996 (05.03.96) * abstract * --	1-13	
A	WO 9630080 A1 (MEDICALDEVICE EMPLOYING MULTIPLE DC ACCELEROMETERS FOR PATIENT ACTIVITY AND POSTURE SENSING), 3 October 1996 (03.10.96) * abstract * --	1-13	
			TECHNICAL FIELDS SEARCHED (Int. Cl.6)
A	US 5354317 A (E.ALT), 11 October 1994 (11.10.94) * abstract * --	1-13	A61N A61B
A	EP 0580128 A2 (E.ALT), 26 January 1994 (26.01.94) * abstract * --	1-13	
A	US 5593431 A (T.J,SHELDON), 14 January 1997 (14.01.97) * abstract * -----	1-13	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
STOCKHOLM	6 March 1998	KARIN SÄFSTEN

CATEGORY OF CITED DOCUMENTS

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